UCRL-JC-130231abs

The Effect of Carbonate Soil on Transport and Dose Estimates for Long-Lived Radionuclides at U.S. Pacific Test Sites

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The United States conducted a series of nuclear tests at Bikini and Enewetak Atolls in the Marshall Islands from 1941 through 1958 that produced close-in fallout that contaminated islands at these two atolls and some atolls east of Bikini. The people were relocated from the atolls in 1946 and have had a continuing desire to return to their homelands.

We initiated a program in 1974 to determine the cycling and transport of long-lived radionuclides in the atoll ecosystem, and estimate the dose from all exposure pathways for people resettling the islands. About 90% of the estimated dose results from Cesium-137 (^{137}Cs) via the ingestion pathway from uptake of ^{137}Cs into locally grown foods and their consumption by the people [1]. The contribution from Strontium-90 (^{90}Sr) is very small.

^{137}Cs in the coral soils is much more available for plant uptake compared with continental soils of North America and Europe. Soil-to-plant ^{137}Cs median transfer factors (TF) (Bq kg^{-1} dry weight plant/Bq kg^{-1} dry weight soil) for tropical fruits range between 0.8 and 35. This compares with values between 0.005 and 0.5 reported for vegetation in temperate zones [2]. Conversely, ^{90}Sr median TF range from 0.001 to 0.1 at the atolls versus a range from 0.02 to 3.0 for continental silica-based soils [2]. Thus, the uptake of ^{137}Cs and ^{90}Sr in carbonate soils is totally reversed from that observed in silica-based soils.

This very significant difference occurs because coral soils are composed almost entirely of Ca carbonate (with some Mg-Sr carbonate) with varying amounts of organic mater, essentially little or no aliminosilicate material, very low concentrations of potassium, and a soil solution pH range from about 7.8 to 9.0. Enhanced plant uptake of ^{137}Cs can be variously attributed to both the absence of clay mineral binding sites and the low concentration of potassium in the soil. Hence, the knowledge of preferential uptake of ^{137}Cs into locally grown food crops was a major contributing factor in (1) reliably predicting the dose for returning residents, and (2) developing a strategy to limit the availability and uptake of ^{137}Cs into locally grown food crops. Had doses at the atolls been calculated using the concentrations of ^{137}Cs and ^{90}Sr in the soil and published transfer factor data for continental soils they would have been in serious error.

Results from experiments indicate that ^{137}Cs is bound in the organic fraction of the soil, whereas ^{90}Sr, Plutonium-239+240 ($^{239+240}$Pu), and Americium-241 (^{241}Am) are primarily bound to the soil moiety. ^{90}Sr can be bound in the carbonate matrix, but moreover, it must compete with extraordinary amount of Ca^{++} in soil solution for plant uptake.

The TF for $^{239+240}$Pu and ^{241}Am are very similar to those observed in continental soils in spite of the high pH and organic content of the soil. They range from 10^{-6} to 10^{-4} for both $^{239+240}$Pu and ^{241}Am. No significant difference is observed between the two in coral soil.

References

[1] Robison, W.L., K.T. Bogen, and C.L. Conrado, "An updated dose assessment for resettlement options at Bikini Atoll—A US nuclear test site," *Health Physics* **73**(1), (1997) 100–114.

[2] International Atomic Energy Agency (IAEA), *Handbook of Parameter Values for the Prediction of Radionuclide Transfer in temperate Environments*, IAEA, Vienna, Austria, Technical Report Series No. 364 (1994).

Work performed under the auspices of the U.S. Department of Energy at Lawrence Livermore National Laboratory under contract W-7405-Eng-48.